Voyager Bulletin

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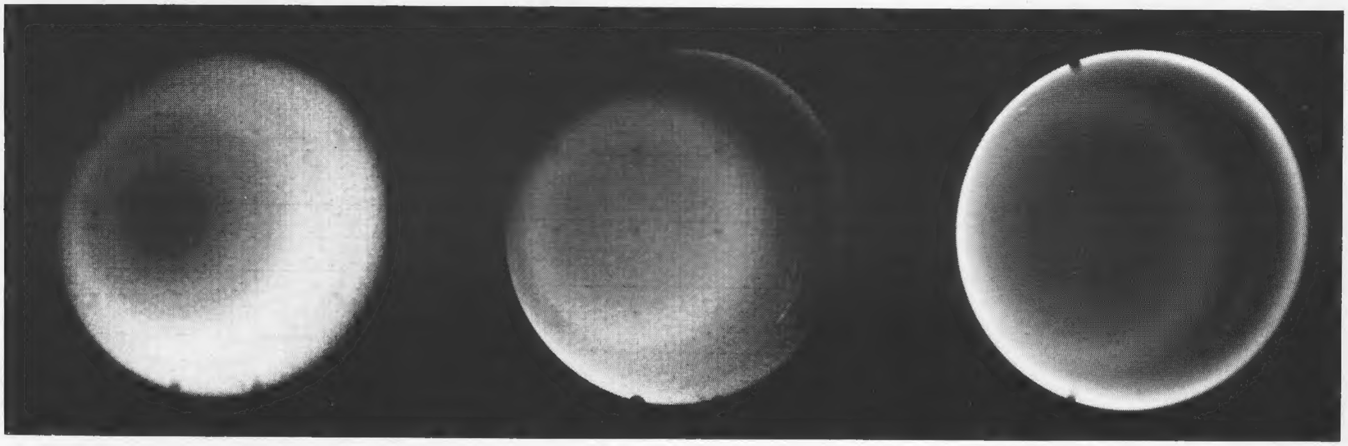


This trio of Voyager 2 images of Uranus shows the varying appearance of the planet as photographed through different color filters of the spacecraft's wide-angle camera. The images were taken January 23, 1986, through the violet, orange and methane filters (displayed in that order, from left). Voyager was 2.1 million kilometers (1.3 million miles) from Uranus; the resolution was 300 km (190 mi). The special properties of the methane filter permit views of the planet in light at a wavelength (0.619 micrometers) that can be strongly absorbed by atmospheric methane. Areas that appear bright in the methane image are generally ones of high clouds, in which the light-scattering particles lie above the methane gas. The discrete bright clouds seen in the methane image (upper left of disk) are probably convective regions where particles have been carried upward above the absorbing methane gas. The dark band at the same latitude is a deeper cloud that lies within the absorbing methane. The region near the very edge of the planet appears bright in the methane image, because the oblique viewing geometry concentrates light scattered from haze at high altitudes, where methane gas is absent. The polar region is one of high haze particles that are dark in violet (left image) relative to the gas molecules. The discrete clouds seen in the orange image (center) and methane image are probably buoyant features of the methane cloud layer that rise to somewhat higher altitudes than the main cloud mass. In violet light, the overlying atmosphere is too opaque to permit these clouds to be seen as easily as in the other filtered images. The darker areas at higher latitudes seen in the violet image may be due to a larger amount of absorbing haze particles in these locations.

"We're happily bewildered," says Voyager Project Scientist Edward Stone of the California Institute of Technology, describing the aftermath of Voyager 2's mad dash through the Uranian system in late January. "We'd be disappointed if we weren't: if it's not bewildering, you haven't learned much!"

Voyager 2 revealed the first planet unknown to the ancients, the first planet discovered by a man we can name, and brought it and its family of moons and rings into our living rooms with startling clarity. For most of us, even the youngest, this will be the only closeup view of Uranus in our lifetime. And we stand with the tired, happy scientists, marvelling at the bizarre surface of Miranda; the cold blue mystery of the planet's atmosphere; the sheet of diverse, enigmatic rings; multiple small dark moons; and a magnetic field that contorts in the solar wind like a double helix. All these were unknown to ancient man, and until a few weeks ago, to modern man as well. This is what it means to be on the cutting edge.

All this brought to us by a one-ton spacecraft designed twelve or more years ago, launched eight-and-a-half years ago, built by thousands, now operated by hundreds.

It is humbling to think that all this can be accomplished with very small onboard computing power. The amount of memory in each of the spacecraft's onboard computers is surpassed by most of today's personal computers. Voyager has three onboard computers, each with two processors. Of course, a large ground support system at JPL, the Deep Space Communications Complexes, and the home institutions of the principal investigators comprise much more computing power for processing and analyzing the data once it is returned to Earth.

The spacecraft's attitude and articulation control subsystem (AACS) and computer command subsystem (CCS) each have two 4-K (18-bit words) plated wire memories, while the flight data subsystem (FDS) consists of two 8-K (16-bit words) semiconductor memories.

Usually, the contents of one computer subsystem's processors are redundant, to safeguard against loss of one processor. The CCS processors operate in parallel, using about 3 K per machine for spacecraft housekeeping and failure protection and only about 1 K per machine (2 K total) for the sequences that direct the spacecraft (and its other two computers) to observe the planets.

During the Uranus mission, some redundancy was given up to reconfigure the second of the two FDS processors to compress image data, allowing transmission of the same amount of information using less than half the number

of bits. This was done by transmitting the brightness of the first pixel in each line of an imaged scene, and then transmitting only the relative difference between adjacent pixels in the remainder of the line. Each image contains 640,000 pixels. Previously, each pixel required 8 bits to describe it and its gray level from 0 to 255. The image data compression technique reduced this requirement to about 3 bits per pixel, cutting the bits per image from 5.12 million to less than 2 million.

The Planet

Almost nothing was known about Uranus before the Voyager encounter, in comparison with knowledge about other planets in our solar system. It lies on its side, its rotational axis lying 8° below the plane of the ecliptic (the plane in which most of the Sun's planets and satellites orbit). It completes an orbit about the Sun every 84 years, exposing its north and south hemispheres to the Sun or to cold deep space for periods as long as 42 years at a time.

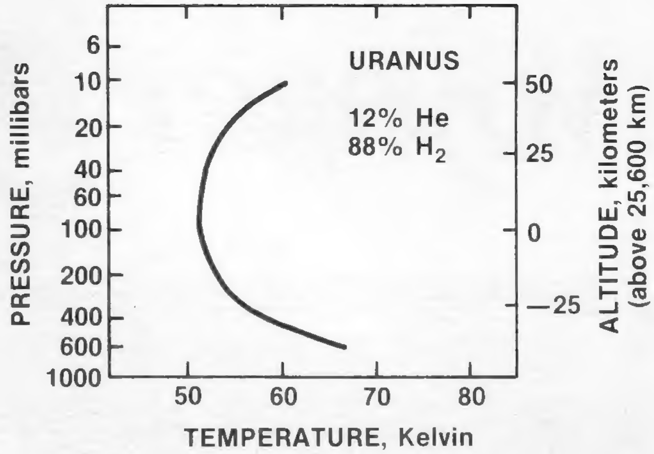
The Earth-orbiting International Ultraviolet Explorer (IUE) spacecraft detected ultraviolet (UV) emissions from the planet, indicating that it might have a magnetic field. (Ultraviolet light is emitted when charged particles spiral into a planet's atmosphere along its magnetic field lines. This phenomenon has been observed at Earth, Jupiter, and Saturn.) The character of a planet's magnetic field gives scientists clues to the planet's interior composition.

Models for the planet's interior supposed a small rocky core about the size of Earth, a deep ocean of water, methane, and ammonia about 10,500 kilometers (6,500 miles) thick, and a dense atmosphere of molecular hydrogen 7,600 kilometers (4,700 miles) thick. Before the Voyager flyby, ground-based observations of Uranus led some theorists to propose that the helium abundance (the ratio of hydrogen to helium) might be as high as 40 percent—way out of scale in comparison to the helium abundance of Jupiter (11 percent) and Saturn (7 percent). Helium abundance is a clue to the early evolution of the planetary nebula and the formation of planets. To first order, all planets should have about the same helium abundance as the Sun. The low abundance on Saturn is due to the precipitation of helium to the interior.

Voyager proved that Uranus does indeed have a quite a large and unusual magnetic field, that its dark pole is surprisingly slightly warmer than its sunlit pole, that its rotation rate is about 17 hours, and that its helium abundance is only about 12 percent, with an uncertainty of 4 percent.

Winds on Uranus blow in the same direction as the planet rotates (opposite to the case on Earth), and at speeds of 15 to 220 meters per second (as compared to Earth's 100 meter per second jet streams 9 kilometers above the Earth's surface).

The average temperature on Uranus is 60 kelvins (K)—a chilling −350° F. The minimum near the tropopause—the boundary between the troposphere (where life abounds on Earth) and the stratosphere—is about 52 K at the one-tenth bar pressure level (the average pressure at sea level on Earth is 1 bar). Between about 15° and 40° latitude, temperatures are 2 to 3 K lower. This band corresponds to a region where cloud streaks have been observed in Voyager images, but what connection there may be between these two observations is still being studied. Temperatures rise above the one-tenth-bar level to as much as 100 K. Below this level, temperatures continue to increase to thousands of kelvins deep in the interior.



The atmosphere of Uranus appears to be about 12 percent helium and 88 percent hydrogen, based on temperature and pressure profiles compiled by radio science data and infrared spectrometry data and compared to theoretical models. This profile was compiled from data acquired as Voyager 2 disappeared behind the planet as seen from Earth, and its radio signal was refracted (bent) by the planet's atmosphere. This refractivity depends on the density and constitutents of the gases in the atmosphere. Radio signals penetrated to about the 2.5 bar pressure level. The temperature at the 100 millibar level (25,600 kilometers from the center of the planet) is about 52 kelvins.

A high-altitude haze layer may include polyacetylene hydrocarbons, possibly produced photochemically. The radio observations reached deep into the atmosphere, to where the pressure is greater than 2.5 bars. This is below the level where methane clouds are believed to form. Temperatures in the atmospheres of Jupiter and Saturn are too warm to allow such methane clouds to develop.

Ultraviolet observations of the atmosphere detected a deep atmosphere of molecular hydrogen over a layer of hydrocarbons, including acetylene.

Uranus also has an extended corona of atomic hydrogen, with temperatures approaching 750 K. On the dayside atmosphere, bright emissions from atomic and molecular hydrogen extend thousands of kilometers above the limb and across the sunlit disk. Similar emissions occur at Jupiter and Saturn, and the term "electroglow" has been coined to describe the phenomena. The cause of the UV emissions is suspected to be photoelectrons which are accelerated to high energies by some still unknown mechanism.

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